INFORMATION SHEET ON DRYING-RATE NOMOGRAPHS III. WHITE POTATO STRIPS--VERTICAL AIR FLOW

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Vegetable dehydrators in which the air stream passes through the bed of vegetable pieces are gaining in popularity in the United States. Their construction is such that a moving belt carries the material through two or more sections, each section acting as a constant-temperature, vertical-flow dehydrator. The design permits the use of high temperatures and high air velocities in the first section where the resulting high evaporation rate keeps the material relatively cool. Before the vegetable pieces are damaged, the belt conveys them to the second section, which is maintained at a lower, and safer, temperature.

A knowledge of the drying curve for the material under specified conditions is essential to a designer or to an operator. Calculation of the performance and characteristics of a dehydrator can be made from the drying curve in combination with the following equations obtained from heat and material balances:

$$F = 0.012 \frac{ML_o}{\theta_f} \tag{1}$$

$$t_d' - t_d'' = \Delta t_d = \frac{1300}{T_o+1} \cdot \frac{L_o}{V} \cdot \frac{\Delta T}{\Delta \theta} \tag{2}$$

$$a'' = a' + 0.0002\,(t_d' - t_d'') \tag{3}$$

$$r = \frac{a' - a_m}{a'' - a_m} \tag{4}$$

$$B = 1300 \left[r + (1-r)\frac{(t_d' - t_m)}{(t_d' - t_d'')} \right] \tag{5}$$

$$D = VM \left[(1-r)(t_d' - t_m) + r\,(t_d' - t_d'') \right] \tag{6}$$

The nomenclature is that used in Information Sheet AIC-31-I except L = belt loading density, M = useful belt area, and V = c.f.m./sq.ft. of useful belt area.

The drying-rate characteristics of 5/32" white potato strips under vertical-air-flow conditions are presented nomographically in this information sheet.

The diagrams included are:

Figure 1 - Drying times for the moisture-content range of $T_o = 4.15$ to $T_o = 0.20$.
Figure 2 - Values of $f(L_o)$ and $f(V)$ to be applied to the data of Fig. 1 only.
Figure 3 - As above, except for the range of $T = 0.20$ to T_f.
Figure 4 - Corrections for Fig. 1 when T_o is greater than 4.15
Figure 5 - Use of layers in designing a heavily-loaded dehydrator.

Figures 1 and 3 are related by the equation:

$$\theta \text{ (at } L_o, V) = \theta_r \cdot f(L_o) \cdot f(V) \qquad (7)$$

where θ_r is evaluated from Fig. 1 (i.e., at reference conditions of L_o = 3 lb./sq.ft. and V = 100 c.f.m./sq.ft.) and where $f(L_o)$ and $f(V)$ are related to L_o and V by Fig. 2. Note that drying times below T = 0.20 are independent of loading density and air velocity.

Use of Nomographs in Designing a Dehydrator

Drying curves for 5/32" white potato strips may be worked out directly from Figures 1, 2, and 3 for loading densities between 0.5 and 4 lb./sq.ft. For heavier loading densities, the drying characteristics of a heavy layer are assumed to be identical to those of a number of light layers in vertical succession. The drying curve for each layer may be obtained by using the same nomographs in combination with equation (2), and the overall drying curve determined by averaging the individual curves. The method of attack is best illustrated by an example:

Problem: A section of a dehydrator is to dry 5/32" white potato strips from $T_o = 4.15$ to $T = 0.60$ at $t_d^{!} = 165°$, $t_w = 95°$, $L_o = 6$ lb./sq.ft., and V = 130 c.f.m./sq.ft. What is the complete drying curve for the section?

Solution: The potato bed is analyzed as two superimposed layers, each loaded at 3 lb./sq.ft. The drying characteristics of the layers must be determined by step-wise calculations. The details of the steps are given below, and Fig. 5 is a graphical representation of the process:

(a) Since Layer 1 is exposed to the incoming air, t_d and t_w are known, and for a selected value of T or Δ T, the corresponding value of θ or $\Delta\theta$ may be determined from the nomographs. Several corresponding values of T and θ establish the drying curve as plotted in Fig. 5. Note that the total drying time to any value of T is proportional to the distance which the belt has carried the material from the feed end.

(b) From the drying curve of Layer 1, the slope, $\Delta T/\Delta\theta$, is calculated over successive increments. The slopes are substituted in equation (2) to determine the temperature of the air leaving the layer at different points

along the bed. The temperature curve corresponding to Layer 1 is drawn in Figure 5.

(c) For Layer 2, t_w is known. A value of $\Delta\theta$ may be selected, and the average air temperature during the time increment may be obtained from the temperature curve of part (b). The nomographs provide the relationship between these variables and the value of ΔT which will occur. Starting at T_o, the drying curve for Layer 2 is thus established by using successive time increments with the result shown in Figure 5.

(d) Equation (2) is applied as under (b) except that the drying curve for Layer 2 is used to determine the proper values of $\Delta T/\Delta\theta$. The resulting temperature curve is that of the air emerging from Layer 2, ready for discarding or recirculating. This curve is also shown in Figure 5.

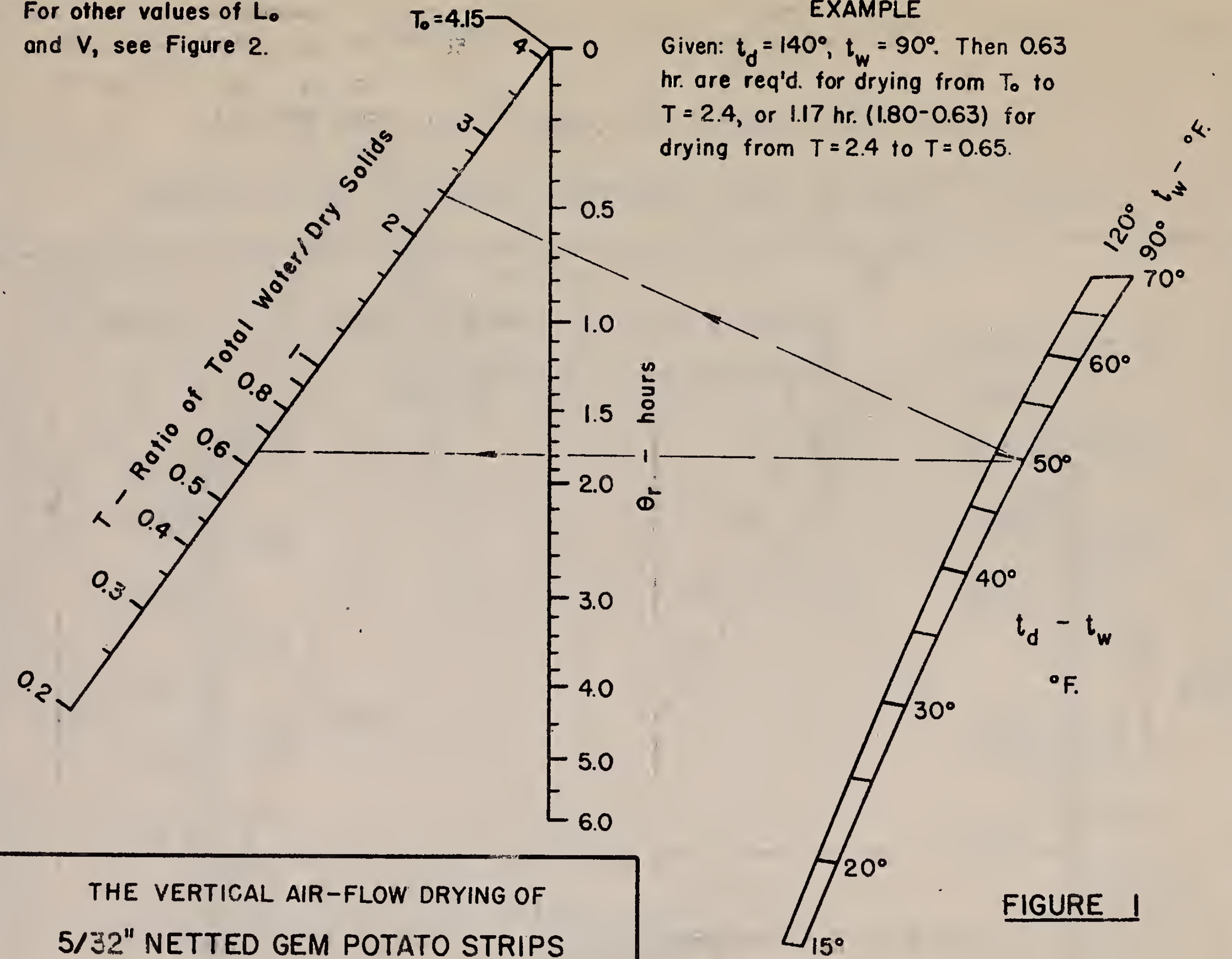
(e) The drying curves for the two layers are combined; i.e., at θ, the two values of T are averaged, in order to obtain the overall drying curve for the potato bed. The total drying time for the section is indicated by the point at which the overall drying curve crosses T = 0.60.

The method outlined above is not limited to two layers, but may be extended as far as necessary to develop the desired loading density. Since the basic nomograph, Figure 1, was established at L_o = 3 lb./sq.ft., combinations of this value are preferred for multiple-layer calculations.

In addition to the drying time, t_d'' must be obtained to permit the solution of equations (1), (3), (4), (5), and (6). The average value of t_d'' may be obtained graphically from the exhaust air temperature curve for the section, or by solving equation (2), using the terminal values of T and θ for the section. The value so obtained is that of the completely mixed exhaust air.

A constant air velocity throughout the section of the dehydrator has been assumed in the foregoing calculations. Suitable construction may permit this condition to exist. If the variations in air velocity along the dehydrator are known, the effect upon the drying time may be evaluated by means of equation (7) and Figure 2 in conjunction with Figure 1. In any case, confusion between θ and θ_r must be avoided. The reference drying time, θ_r, is primarily a tool for using the nomograph of Figure 1. The actual drying time, θ, must be used for plotting drying curves and calculating temperature drops.

Many features may be incorporated into the vertical air flow dehydrator. Air should be recirculated to conserve heat, and the exhaust air from a following section should be fed to the intake of the preceding section. The use of updraft and downdraft in alternate sections tends to make the moisture content of the material more uniform at different levels in the bed. High air velocities may be used where the greatest benefit is obtained, and lower air velocities used as the material becomes drier, thus saving power. The quantitative effect of such design possibilities may be predicted only by calculations of the type outlined in this information sheet.



For other values of L_o and V, see Figure 2.

EXAMPLE

Given: $t_d = 140°$, $t_w = 90°$. Then 0.63 hr. are req'd. for drying from T_o to $T = 2.4$, or 1.17 hr. (1.80-0.63) for drying from $T = 2.4$ to $T = 0.65$.

THE VERTICAL AIR-FLOW DRYING OF

5/32" NETTED GEM POTATO STRIPS

DOWN DRAFT $T_o = 4.15$ to $T = 0.20$

$L_o = 3.0$ LB./SQ.FT. V = 100 C.F.M./SQ.FT.

$t_d = 120°$ to 160°F. $t_w = 90°$ to 120°F.

FIGURE 1

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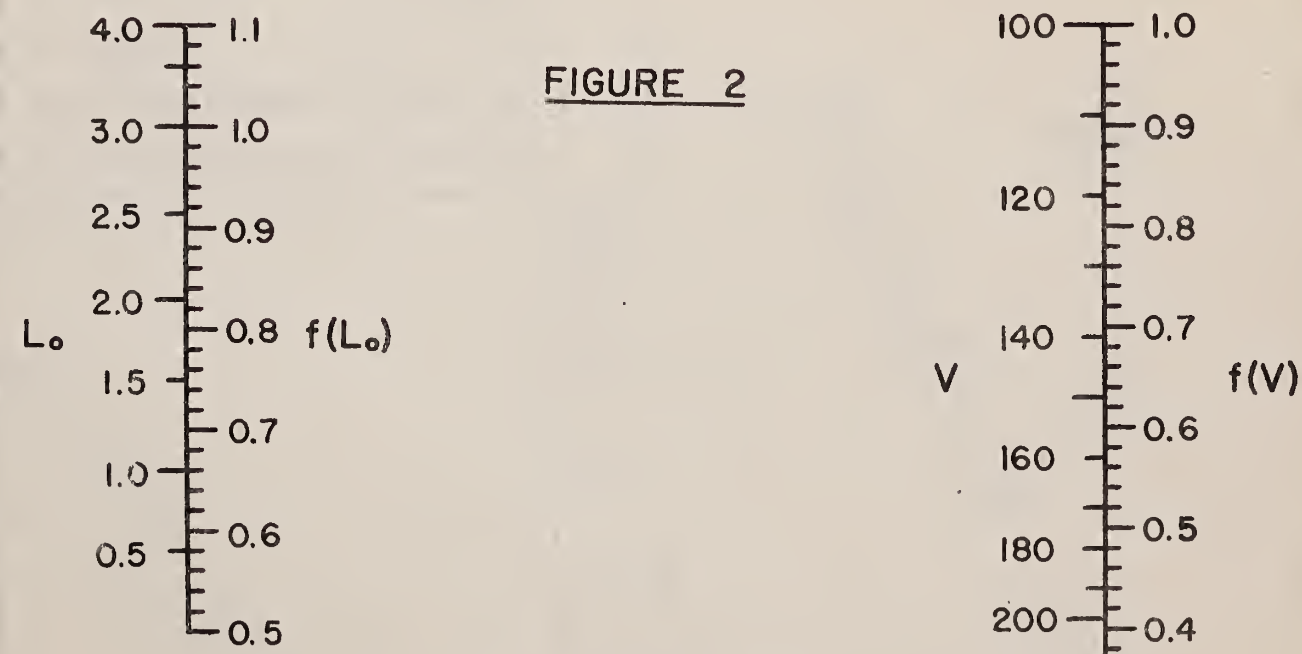
A.H.B.

FIGURE 2



For use only in the moisture-content range of T_o to $T = 0.20$.

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A.H.B.

EFFECT OF LOADING DENSITY AND OF AIR VELOCITY

VALUES OF $f(L_o)$ AND $f(V)$ FOR EQUATION (1)

THE VERTICAL AIR-FLOW DRYING OF 5/32" NETTED GEM POTATO STRIPS

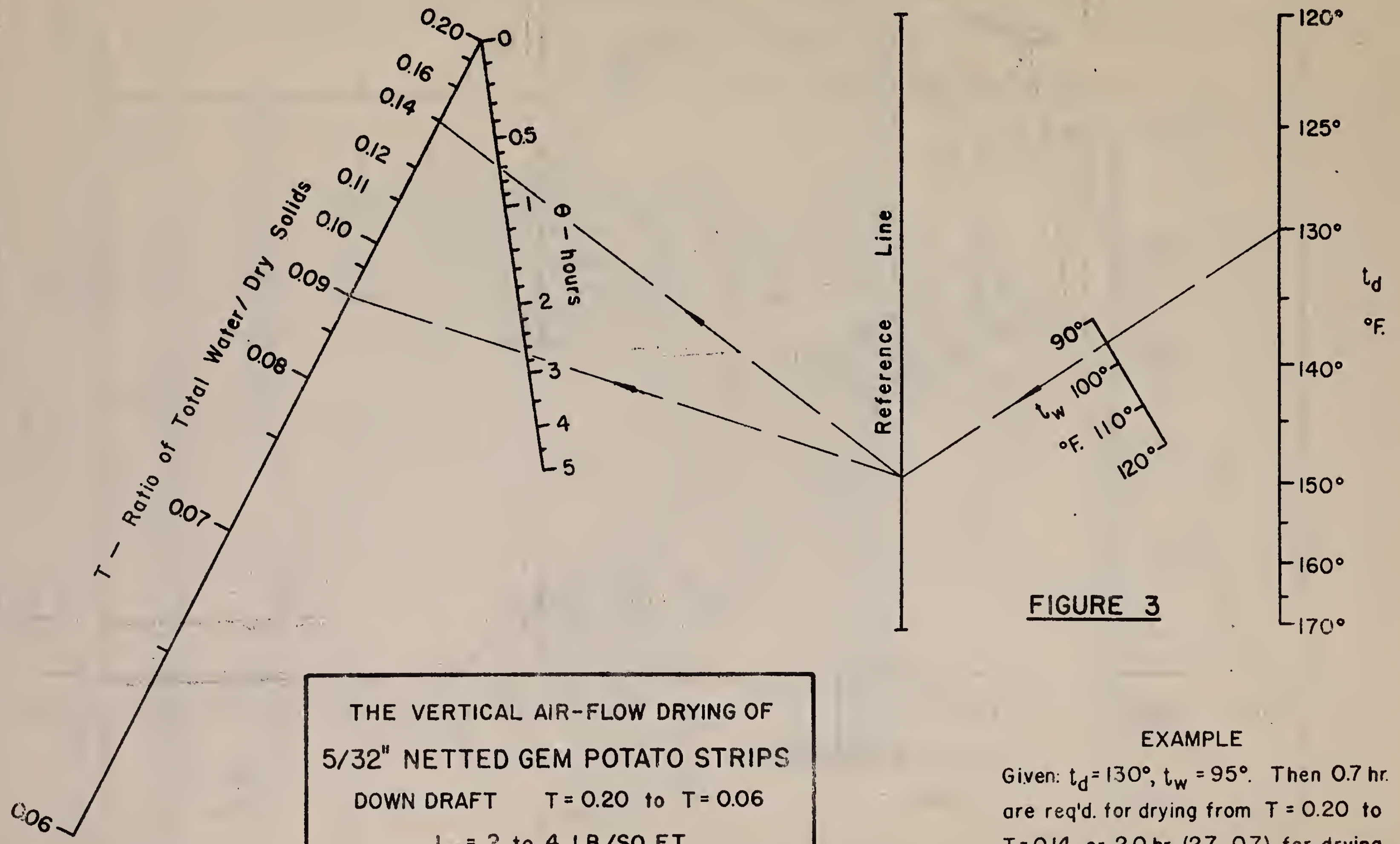

FIGURE 3

THE VERTICAL AIR-FLOW DRYING OF

5/32" NETTED GEM POTATO STRIPS

DOWN DRAFT T = 0.20 to T = 0.06

L_o = 2 to 4 LB./SQ.FT.

V = 100 to 350 C.F.M./SQ.FT.

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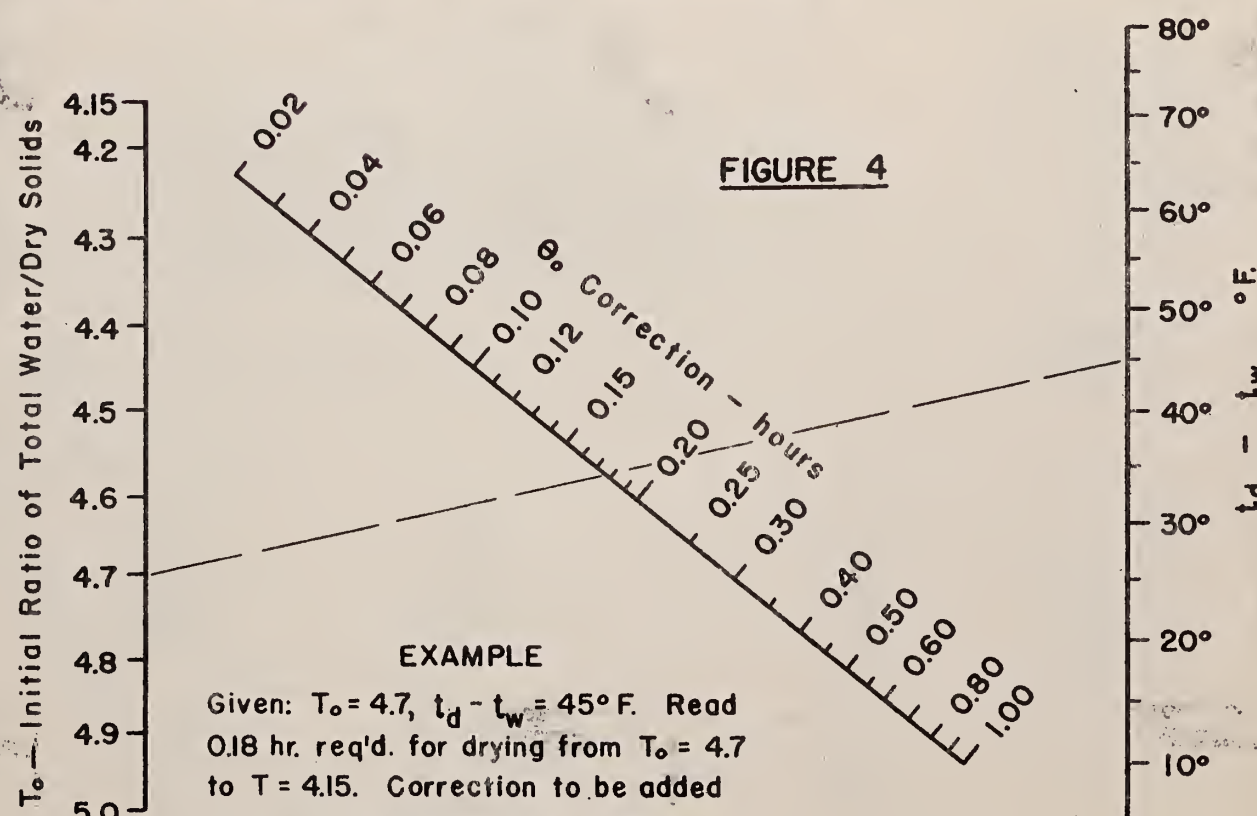
A.H.B.

EXAMPLE

Given: $t_d = 130°$, $t_w = 95°$. Then 0.7 hr. are req'd. for drying from T = 0.20 to T = 0.14, or 2.0 hr. (2.7-0.7) for drying from T = 0.14 to T = 0.09.

FIGURE 4



EXAMPLE

Given: $T_o = 4.7$, $t_d - t_w = 45°$ F. Read 0.18 hr. req'd. for drying from $T_o = 4.7$ to $T = 4.15$. Correction to be added to θ_r as obtained from Figure

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A. H. B.

θ_o CORRECTION FOR $T_o > 4.15$

THE VERTICAL AIR-FLOW DRYING OF 5/32" NETTED GEM POTATO STRIPS

V = 100 C.F.M./SQ.FT. DOWN DRAFT $\qquad$ L_o = 3.0 LB./SQ.FT.

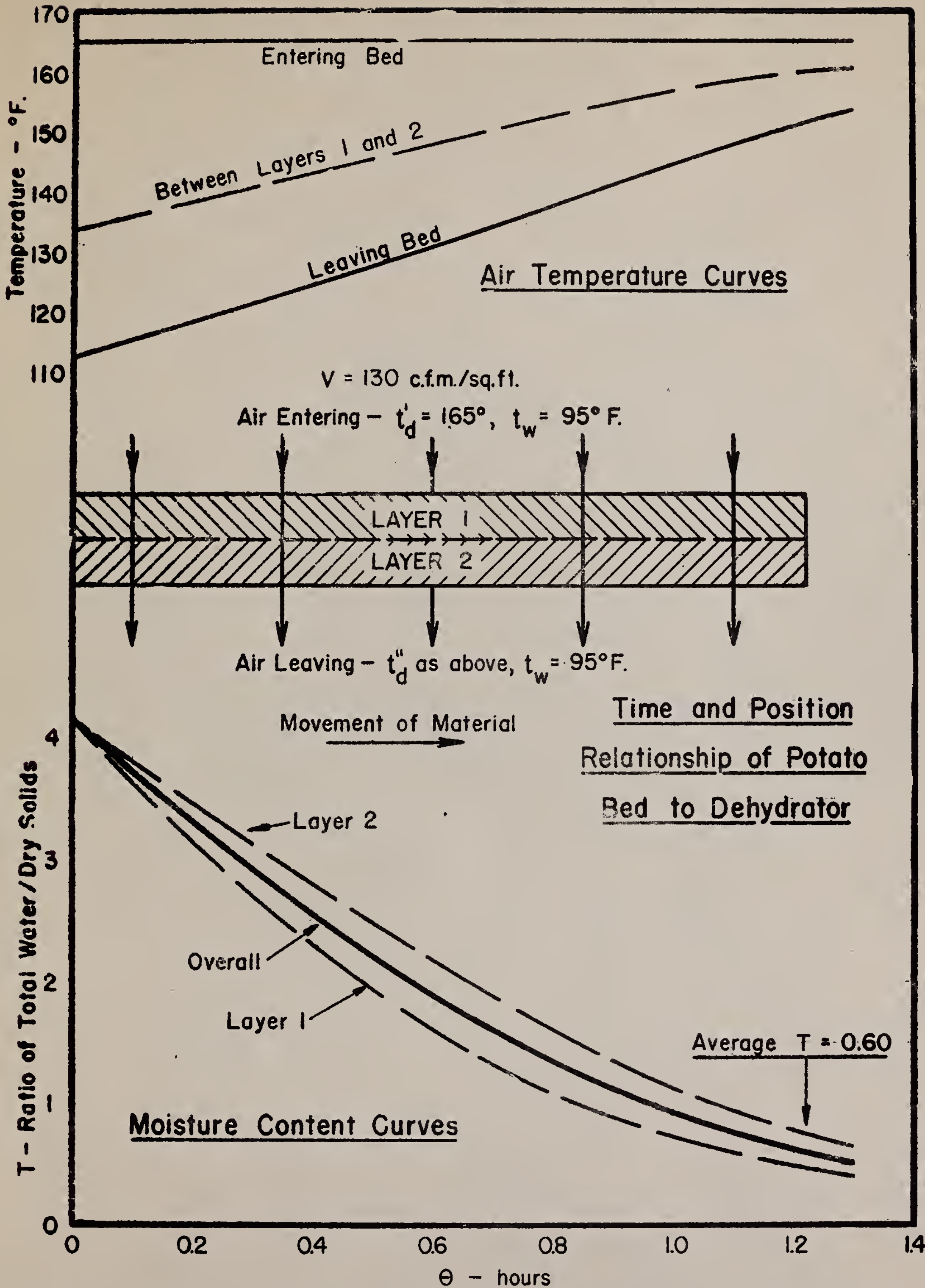

FIGURE 5 – DESIGNING OF HEAVILY-LOADED DEHYDRATORS BY USE OF LAYERS